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BENEFICIATION OF A SAMPLE OF SILICA FROM SUSSEX, NEW BRUNSWICK

P.R.A. Andrews
Mineral Processing Laboratory

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BENEFICIATION OF A SAMPLE OF SILICA FROM SUSSEX, NEW BRUNSWICK

by

P.R.A. Andrews*

SUMMARY

A sample of silica from Sussex, New Brunswick was beneficiated by scrubbing and washing to remove slime clay and by magnetic separation and spiral concentration to remove iron and titanium minerals. The optimum concentration was obtained in the -420 + 105 µm fraction where a sand product analysing 99.48% SiO_2, 0.04% Fe_2O_3 and 0.17% Al_2O_3 was obtained. Although the iron oxide and alumina contents are slightly in excess of those required for glass sands (0.03% Fe_2O_3 and 0.15% Al_2O_3), further scrubbing and washing would reduce the alumina (but not the iron oxide) to more acceptable levels.

Spiral concentration was not as successful in reducing iron and titanium oxides levels as high intensity magnetic separation. Spiral concentration removed 33.0% of the iron oxides and 63.4% of the titanium oxides, whereas magnetic separation removed 80.7% of the iron oxides and 75.4% of the titanium oxides.

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*Research Scientist, Ore Dressing Section, Mineral Processing Laboratory, Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, Ottawa.

ENRICHISSEMENT D'UN ÉCHANTILLON DE SILICE EN PROVENANCE DE SUSSEX NOUVEAU-BRUNSWICK

par

P.R.A. Andrews*

RÉSUMÉ

L'enrichissement d'un échantillon de silice en provenance de Sussex, Nouveau-Brunswick, a été effectué par épuration et lavage dans le but d'éliminer la boue limoneuse et par séparation magnétique et concentration en spirale pour retirer les minerais de fer et de titane. La concentration optimale du minerai s'est produite à partir de la fraction -420 + 105 µm de laquelle un produit sableux titrant 99,48 % SiO_2, 0,04 % Fe_2O_3 et 0,17 % Al_2O_3 a été obtenu. Bien que la teneur en oxyde de fer et en alumine soit légèrement supérieure à celle requise des sables convenant pour la fabrication du verre, (0,03 % Fe_2O_3 et 0,15 % Al_2O_3), une épuration et un lavage en profondeur réduiraient la teneur en alumine (mais non en oxyde de fer) à des niveaux plus acceptables.

La concentration en spirale n'a pas réussi à réduire les niveaux d'oxyde de fer et de titane à l'instar de la séparation magnétique à haute densité. La concentration en spirale a permis d'éliminer 33,0 % des oxydes de fer et 63,4 % des oxydes de titane tandis que la séparation magnétique a permis d'éliminer 80,7 % des oxydes de fer et 75,4 % des oxydes de titane.

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*Chercheur scientifique, Section de la minéralurgie, Laboratoire de traitement des minéraux, Centre canadien de la technologie des minéraux et de l'énergie, Énergie, Mines et Ressources Canada, Ottawa.

INTRODUCTION

In October 1984, approximately 130 kg of damp silica in three drums was received from a deposit in Sussex, New Brunswick, for evaluation as source material for silica sand or glass sand manufacture.

Glass sand specifications usually stipulate that all sand should be between 600 and 100 µm in size, and have the following minimum chemical analyses: 99.6% SiO_2, 0.03% Fe_2O_3, 0.15% Al_2O_3, with low lime and magnesia. Iron and steel foundry sands vary in grain size between 850 and 75 µm in closely sized ranges. AFS (American Foundryman's Society) numbers vary between 55 and 65, with the bulk of the sand preferably being on three adjacent sieves. A rounded grain shape is preferred. The quartz content should be high, 99% SiO_2, with low aluminium, iron, sodium and potassium oxides; the last three act as fluxing agents and are therefore particularly troublesome.

SAMPLE DESCRIPTION

The appearance of the sample was granular with a considerable quantity of sticky clay material, which occurred as 100 mm 'ball' agglomerates of quartz and clay. The size of the quartz ranged from 150 mm rounded pebbles to -105 µm slime.

MINERALOGY

A -600 µm head sample was evaluated by mineralogical analysis to identify the minerals present and to provide an approximate estimate of the type and amount of mineral inclusions in the quartz. Polished sections were prepared and representative areas chosen for scanning electron microscopy.

The quartz was sub-angular and accounted for approximately 90% of the sample. The remaining portion was composed of garnet, ilmenite, goethite, rutile and mica. A few quartz grains with minute particles of pyrite or rutile attached to the quartz rims were present.

SCOPE OF STUDY

To preserve the shape of the quartz grains wet screening rather than mulling was chosen as the preliminary beneficiation stage, to remove fine clay. Clay which remained unliberated, i.e. in the form of 100 mm agglomerates, could be broken up by hand. After drying and sizing, the -420 µm + 105 µm (-40 + 140 mesh) fraction was used for comparing results using wet and dry high intensity magnetic separation. Wet magnetic separation was also assessed on a sample which had been subjected to moderate scrubbing. A comparison was also made between magnetic separation and spiral concentration, since spiral concentration is considerably cheaper than magnetic separation, and can be used to remove rutile and ilmenite, both of which were identified in the sample.

PROCESSING

HEAD SAMPLE

Because of the damp nature of the sample it was not practical to riffle a head sample; a grab sample was taken from each of the three drums for moisture determination and chemical analysis. The moisture content of this sample was 4.2%; the chemical analysis is reported in Table 1.

WET SCREENING

The entire sample was passed over a laboratory 'circle throw' wet vibrating screen, fitted with a 6.7 mm screen. The undersize was fed to a large container with a spout overflow, so that the fine clay could be decanted; the oversize was repassed over the screen. After completion of screening both the +6.7 mm and -6.7 mm fractions were further washed by hand to break up the agglomerates of quartz and clay, so that all fine clay could be removed from both fractions. After drying, both fractions were dry screened; the resulting size analysis is presented in Table 2.

MAGNETIC SEPARATION

For evaluation by magnetic separation, four 5 kg samples and a 200 g sample were prepared from the -420 µm + 105 µm fraction.

The 200 g sample was passed through the Sala HGMS (wet high gradient magnetic separator), set at maximum current rating, and the non-magnetic and magnetic fractions were prepared for chemical analysis. A 5 kg sample was passed through the Exolon high intensity dry magnetic separator set at maximum current rating of 2lA. The non-magnetic and magnetic fractions were similarly prepared for chemical analysis; the results of wet vs dry magnetic separation on unscrubbed silica sand are presented in Table 3.

The remaining three 5 kg samples were each subjected to scrubbing prior to magnetic separation. The samples were scrubbed in a laboratory Wemco scrubber at 85% solids for 5, 10, and 15 min, respectively. After decanting and washing to remove -105 µm slime, the scrubbed products were dried and chemically analysed. A 200 g sample was riffled from each scrubbed product for magnetic separation using the Sala HGMS. As before, the non-magnetic and magnetic fractions were prepared for chemical analysis, and the results are presented in Table 4.

Finally, the 10 min scrubbed product was further divided into two portions; one portion was screened at 300 µm (50 mesh) and the other at 210 µm (70 mesh); screen fractions were prepared for chemical analysis. In addition, 200 g portions were prepared from the -300 µm + 105 µm and -210 µm + 105 µm fractions and subjected to magnetic separation using the Sala HGMS. The non-magnetic and magnetic fractions as before were prepared for chemical analysis. Results are presented in Table 5.

SPIRAL CONCENTRATION

Since magnetic separation is a costly capital expenditure, a less expensive alternative for removing the heavy minerals was considered. Spiral concentration is both cheaper than magnetic separation and has been used successfully to beneficiate ilmenite and rutile.

Seventy kg of -840 µm unscrubbed silica sand was obtained for spiral concentration tests. The moisture content was determined at 12% and chemical and size analyses are reported in Tables 6 and 7.

Since the sample had been pre-screened at 840 µm, it was necessary only to employ scrubbing to remove clay and iron oxides. The laboratory Wemco scrubber was used for this purpose, using 10 kg batches at 85% solids pulp density and 30 min scrubbing time. After washing to remove -105 µm clay slimes, the scrubbed products were dried and approximately 20 kg riffled for a spiral concentrator test.

The 20 kg sample was mixed at 45% solids pulp density in a conditioner which discharged into a Mark 7A spiral. The spiral concentrate, middlings and tailings discharged into a 3.8 cm vertical Sala pump which returned the slurry to the conditioner. When the system was operating in equilibrium, samples of spiral concentrate, middling and tailing were obtained. A second test was conducted at 40% solids for comparison purposes. Results are reported in Table 8.

The middling and tailings products from both tests were combined and treated in the Exolon high intensity magnetic separator to determine whether any further magnetic material would be removed. For comparison, a sample of the spiral concentrator feed also was treated in the Exolon magnetic separator. Results are reported in Table 9.

RESULTS

In addition to the head sample, each scrubbed product, magnetic separation and spiral concentration test product, was analysed for those oxides normally associated with silica deposits; the results are reported in Tables 10 and 11.

On the basis of scrubbing alone, the optimum product analysis was 99.03% SiO_2 in the -420 + 210 µm fraction. The levels of alumina, at 0.39% Al_2O_3, and iron oxides at 0.16% Fe_2O_3, were unacceptably high due probably to inadequate scrubbing and removal of slimes. Magnetic separation using the Sala high intensity separator with the -420 + 105 µm fraction further improved product analysis to 99.48% SiO_2 by reducing the iron oxide content to 0.04% Fe_2O_3; the alumina was reduced to 0.17% Al_2O_3.

Spiral concentration was only partially successful in removing iron and titanium oxides. The results reported in Table 8 indicate that better rejection was achieved at 40% solids than 45% solids pulp density, but even at 40% solids only 33.0% of the iron oxides and 63.4% of the titanium oxides were removed. A comparative test conducted on spiral feed using the Exolon magnetic separator, results reported in Table 9, removed 80.7% of the iron oxides and 75.4% of the titanium oxides.

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TABLE 1. Head sample, chemical analysis

Constituent Oxides	Analysis %
SiO_2	95.67
Al_2O_3	2.51
Fe_2O_3	0.23
TiO_2	0.08
Cr_2O_3	0.02
ZrO_2	0.02
CaO	0.11
MgO	0.18
Na_2O	0.02
K_2O	0.12
LOI	1.04
TOTAL	100.00

TABLE 2. Head sample, size analysis

Size	Weight %
+63.5 mm	1.5
- 63.5 +38.1 mm	0.6
- 38.1 +18.9 mm	2.5
- 18.9 + 9.4 mm	7.8
- 9.4 + 6.7 mm	1.2
- 6.7 + 3.4 mm	11.9
- 3.4 + 420 µm	39.3
- 420 + 105 µm	17.7
- 105 µm	17.4
Calculated Head	100.0

TABLE 3. Comparison of iron removal by wet and dry magnetic separation (-420 +105 μm unscrubbed sand)

Wet magnetic separation

Sala products	Weight %	Analysis % Fe_2O_3	Distribution %
Magnetics	5.07	4.89	78.85
Non-magnetics	94.93	0.07	21.15
Calculated head	100.00	0.31	100.00

Dry magnetic separation

Exolon products	Weight %	Analysis % Fe_2O_3	Distribution %
Magnetics	4.53	5.98	84.18
Non-magnetics	95.47	0.05	15.82
Calculated head	100.00	0.32	100.00

TABLE 4. Comparison of iron removal using wet magnetic separation on -420 +105 µm quartz scrubbed for 5, 10 and 15 min

Scrubbing time	Sala products	Weight %	Analysis % Fe_2O_3	Distribution %
5 min	Magnetics	4.80	4.73	85.62
	Non-magnetics	95.20	0.04	14.38
	Calculated head	100.00	0.27	100.00
10 min	Magnetics	4.66	4.62	84.97
	Non-magnetics	95.34	0.04	15.03
	Calculated head	100.00	0.25	100.00
15 min	Magnetics	3.99	5.26	78.47
	Non-magnetics	96.01	0.06	21.53
	Calculated head	100.00	0.27	100.00

TABLE 5. Comparison of iron removal using wet magnetic separation between -300 + 105 µm and -210 +105 µm fractions (10 min scrubbing)

Size range µm	Sala products	Weight %	Analysis % Fe_2O_3	Distribution %
-300 +105	Magnetics	4.80	6.37	82.12
	Non-magnetics	95.20	0.07	17.88
	Calculated head	100.00	0.37	100.00
-210 +105	Magnetics	5.34	7.67	87.82
	Non-magnetics	94.66	0.06	12.18
	Calculated head	100.00	0.47	100.00

TABLE 6. Head sample, chemical analysis for spiral concentrator test

Constituent Oxides	Analysis %
SiO_2	96.00
Al_2O_3	1.48
Fe_2O_3	0.96
TiO_2	0.59
CaO	0.01
MgO	0.10
Na_2O	n.d.
K_2O	n.d.
LOI	n.d.
TOTAL	99.14

TABLE 7. Head sample, size analysis for spiral concentrator test

Size µm		Weight %
	+630	7.7
-630	+400	21.1
-400	+315	17.0
-315	+200	26.6
-200	+160	6.7
-160	+100	8.4
-100		12.5
TOTAL		100.0

TABLE 8. Evaluation of spiral concentration using -840 + 105 µm quartz at 40% and 45% solids

Pulp Density	Products	Weight %	Analysis % Fe_2O_3	Analysis % TiO_2	Distribution % Fe_2O_3	Distribution % TiO_2
45% s	Concentrate	2.3	6.16	7.02	28.2	55.8
	Middling	12.0	1.00	0.71	23.9	29.4
	Tailing	85.7	0.28	0.05	47.9	14.8
	Calculated head	100.0	0.50	0.29	100.0	100.0
	Middlings & tailings	97.7	0.37	0.13	71.8	44.2
40% s	Concentrate	2.3	8.32	10.20	33.0	63.4
	Middling	9.9	1.53	1.01	26.1	27.1
	Tailing	87.8	0.27	0.04	40.9	9.5
	Calculated head	100.0	0.58	0.37	100.0	100.0
	Middlings & tailings	97.7	0.40	0.14	67.0	36.6

TABLE 9. Comparison of dry magnetic separation on spiral feed, and combined spiral middling and tailings

1. Spiral feed

Products	Weight %	Analysis % Fe_2O_3	Analysis % TiO_2	Distribution % Fe_2O_3	Distribution % TiO_2
Magnetics	2.1	29.7	19.6	80.7	75.4
Middlings	3.1	1.75	1.43	7.0	8.1
Non-magnetics	94.8	0.10	0.10	12.3	16.5
Calculated head	100.0	0.77	0.54	100.0	100.0

2. Combined spiral middling and tailings

Products	Weight %	Analysis % Fe_2O_3	Analysis % TiO_2	Distribution % Fe_2O_3	Distribution % TiO_2
Magnetics	1.0	34.6	6.37	45.9	18.1
Middlings	3.8	1.17	0.34	5.9	3.7
Non-magnetics	92.9	0.11	0.05	15.2	14.8
Calculated head	97.7	0.45	0.12	67.0	36.6
Measured head	97.7	0.40	0.14		

TABLE 10. Summary of chemical analysis of scrubbed products

Products µm	Scrubbing time, min	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Cr_2O_3	ZrO_2	CaO	MgO	Na_2O	K_2O	LOI	Total
-420 + 105	0	97.68	0.88	0.30	0.38	0.003	0.033	0.07	0.04	0.03	0.08	0.36	99.86
-420 + 105	5	98.03	0.70	0.31	0.33	0.005	0.054	0.06	0.03	0.02	0.02	0.35	99.91
-420 + 105	10	98.17	0.60	0.32	0.29	0.005	0.046	0.06	0.03	0.02	0.01	0.33	99.88
-420 + 105	15	98.00	0.55	0.28	0.30	0.006	0.045	0.06	0.02	0.02	0.06	0.27	99.61
-420 + 210	10	99.03	0.39	0.16	0.038	0.003	0.006	0.04	0.02	0.01	0.01	0.20	99.91
-420 + 300	10	98.83	0.42	0.16	0.034	0.003	0.004	0.05	0.02	0.01	0.01	0.31	99.85
-300 + 105	10	97.37	0.88	0.42	0.60	0.006	0.081	0.06	0.03	0.02	0.02	0.33	99.82
-210 + 105	10	96.70	0.75	0.51	0.97	0.012	0.10*	0.07	0.03	0.03	0.08	0.32	99.57

*The limit of spectrographic analysis detection for ZrO_2 is 0.1%. It would seem that the true analysis is not much higher than 0.1%, since the total sample (-210 +105 µm) composite anlysis is 99.57%.

TABLE 11. Summary of chemical analyses of non-magnetic fractions

Products µm	Scrubbing time, min	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Cr_2O_3	ZrO_2	CaO	MgO	Na_2O	K_2O	LOI	Total
Wet non-magnetic fraction from Sala													
-420 + 105	0	99.21	0.28	0.07	0.057	0.002	0.034	0.03	0.01	0.01	0.04	0.18	99.92
-420 + 105	5	99.44	0.17	0.04	0.032	0.003	0.016	0.03	0.01	0.01	0.02	0.14	99.91
-420 + 105	10	99.48	0.17	0.04	0.033	0.003	0.020	0.03	0.01	0.01	0.02	0.15	99.97
-420 + 105	15	99.29	0.19	0.06	0.044	0.002	0.030	0.03	0.01	0.01	0.02	0.14	99.83
-300 + 105	10	99.46	0.23	0.07	0.077	0.003	0.048	0.03	0.01	0.01	0.04	0.13	100.11
-210 + 105	10	99.41	0.26	0.06	0.078	0.002	0.093	0.04	0.01	0.01	0.04	0.14	100.14
Dry non-magnetic fraction from Exolon													
-420 + 105	0	99.33	0.21	0.03	0.028	0.003	0.022	0.04	0.02	0.01	0.02	0.16	99.87